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PROGRESS REPORT #3

INVESTIGATION OF THE EFFECTS OF EXTERNAL CURRENT SYSTEMS ON THE MAGSAT DATA UTILIZING GRID CELL MODELING TECHNIQUES

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16. Abstract

The overall objective of this effort in support of the Magsat project is to study the feasibility of modeling magnetic fields due to certain electrical currents flowing in the earth's ionosphere and magnetosphere. This third quarterly status and technical progress report discusses efforts devoted to reading Magsat data tapes in preparation for further analysis of the Magsat data. The report also describes refinements to the modeling procedure that is being developed to compute the magnetic fields at satellite orbit due to current distributions in the ionosphere and magnetosphere. The modeling technique utilizes a linear current element representation of the large-scale space-current system. A model polar current system is presented and magnetic field perturbations resulting from this system are computed along two hypothetical satellite orbits.

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I. INTRODUCTION

The overall goal of this investigation is to study the feasibility of modeling the magnetic fields produced by certain electrical currents flowing in the earth's ionosphere-magnetosphere system. Vector magnetic field measurements from the near-polar orbiting Magsat satellite contain, in addition to the main geomagnetic field and crustal anomaly fields, contributions that arise from these external currents. In meeting the ultimate goals of the Magsat project, it is desirable that the external current effects be identified in the observations and subsequently separated from the internal field. The objective of this investigative effort will be to determine the capability of a modeling procedure to facilitate the separation of these external and internal components.

The approach of this feasibility study shall be to develop forward modeling procedures through which the magnetic effects of model currents may be derived. It is intended to include, separately, the equatorial electrojet, S_q currents, and the effects due to auroral zone and polar cap currents including the high latitude ionosphere-magnetosphere coupling currents. In each case candidate current systems will be devised and resulting "typical" magnetic field signatures calculated for comparison with Magsat observations.

II. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Reduction

In previous quarterly reports, we discussed the development of software programs to read the Magsat Chronicle format data tapes on a U.T.D. PDP 11/45 computer, and printout either the orbital data alone or both orbital and magnetic field-values from both scalar and vector magnetometers for any specified time period contained on the source tape.

The program computes geodetic longitude and latitude, and altitude of the spacecraft and outputs this information along with inertial and magnetic coordinate positions. The magnetic field measurements during each second are read and the maximum, minimum, and average values for each scalar head and each vector component are printed at one-second intervals. This software package is being extended so that selected portions of Magsat data can be stored on disc. Additional data reduction software will access the stored data, subtract a model field, and plot the resultant magnetic component deviations on a high resolution interactive vector graphics terminal. This will permit direct comparisons between the measured magnetic field perturbations and the model results described below.

2. Field Modeling

Previous quarterly reports have described a modeling technique that is being developed to compute the magnetic effects at Magsat altitudes due to hypothetical currents in and above the high latitude ionosphere. In this forward modeling technique prototype current systems representing the auroral electrojet and ionospheric polar cap currents as well as the field-aligned currents that link these low altitude currents to the distant magnetosphere are devised. This current system is then represented for computational purposes as an array of linear current elements having finite length and a finite diameter with a pre-determined cross-sectional current density distribution within each element. For each observation point along a hypothetical satellite orbit, the three vector components of the resultant magnetic field are computed as a superposition of the field contributions due to each current element in the world-space. The resultant magnetic perturbations for each vector-field component are displayed on a high resolution vector graphics terminal by means of a computer program designed to allow the operator to interactively modify the model

parameters. The initial stages of development of this model discussed in the first quarterly report had been restricted to satellite orbits at 90° inclination in the dawn-dusk meridian plane and the initial computations included only the sunward component of the perturbation field at various altitudes. During the second quarter the capabilities of the model were extended to allow the computation of three vector components of the magnetic field arising from a prototype current system. Furthermore, the restriction on satellite orbits was almost entirely eliminated allowing the magnetic field components to be computed for virtually any satellite orbit over a wide range of inclinations and altitudes and having an arbitrary angle between the orbital plane and the earth-sun line.

Two major extensions of the magnetic field modeling software have been made during the present reporting period that significantly extend the ability of the model to handle realistic current systems and present the results more realistically. The capability for ionospheric current closure in the east-west direction has now been built into the model. Furthermore the resulting magnetic field perturbations may now be computed and plotted in an N,E,V coordinate system.

Figure 1 is a schematic representation in magnetic local time-magnetic latitude coordinate system of the linear current elements used to model to zeroth order the naturally occurring field-aligned currents above the high latitude ionosphere. Each circle with its appropriate cross-hatching represents the location, current intensity, and current flow direction for a linear current element. The superposition of all these current elements approximate a "classical" large-scale Birkeland sheet current model with downward directed currents in the high latitude postmidnight and the low latitude pre-midnight portions and upward directed currents in the high latitude pre-midnight and low latitude post-midnight sectors. For this particular instance low-level distributed inward field

aligned currents exist between 0800 and 1600 hours on the dayside and similar outward directed currents appear on the nightside. These distributed currents are necessary to maintain continuity of the horizontal ionospheric closure currents shown in Figure 2. In this figure the arrows represent the direction and relative magnitude of the Hall and Pedersen ionospheric closure currents. For the current system illustrated here the majority of the Birkeland current closure occurs in the N-S direction with the eastward and westward closure currents becoming proportionally stronger near the dusk and dawn sectors respectively and decreasing to zero near noon and midnight.

Figures 3 and 4 depict the magnetic perturbations that would be observed by magnetometers on a satellite along two hypothetical orbits that pass through the modeled current system at an altitude of 450 km. In each figure the upper panel shows the latitudinal profile of the three vector components of B in an XYZ coordinate system while the center panel depicts the field components in the more conventional N,E,V coordinate system. Shown in the bottom panel of Figures 3 and 4 are the field-aligned current densities encountered at each point along the satellite orbit. The clock dial in the upper right quadrant depicts the satellite orbit in a Magnetic Local-Time and Invariant Latitude coordinate system. In Figure 3 the satellite has an orbital inclination of 90° and its orbital plane is contained in the dawn-dusk meridian. As expected the major perturbation in the magnetic field appears in the east-west component and has its greatest gradient co-located with the local field-aligned current. In Figure 4 a slightly different orbit has been chosen with an orbital inclination of 6° . Now the satellite passes slightly to the dayside of the dawn-dusk meridian. Comparison with Figure 3 reveals that the east-west magnetic component is virtually unchanged whereas a substantial N-S component has now developed in the magnetic field. This kind of comparison illustrates the strong effect that relatively small

displacements in the location of the measuring point can have upon the vector magnetic field.

3. Other Activities

During this quarter a paper was presented at the spring annual meeting of the American Geophysical Union entitled " A Method of Calculating Magnetic Fields due to Systems of Distributed Currents." An abstract of this paper was appended to the last quarterly report.

III. PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

No major problems have been encountered.

IV. PLANS FOR NEXT REPORTING INTERVAL

Although the primary goal of this effort is to develop field modeling techniques for the near-earth magnetic field arising from external currents, such development cannot successfully be carried out without concomitant study and analysis of the actual Magsat Data. Hence during the forthcoming quarter the development of data reduction software will continue. Development of computer routines to store selected portions of Magsat data on disc file for subsequent analysis and plotting is continuing. In particular, routines will be developed and integrated into our existing software to compute the geopotential magnetic field at Magsat and to subtract this model field from the Magsat measured field. The resultant perturbations in the scalar magnitude and in each of the 3 vector components will then be plotted by interactive graphics routines designed to allow flexibility in plotting format.

Further development of the linear element field modeling procedure will take place during the next reporting period. The emphasis will be placed upon utilizing the flexibility built into the software to choose a diverse range of initial current configurations. It is also planned that the modeling technique shall ultimately include effects due to currents in the S_q current system and in the equatorial electrojet. These currents have not until now

been included in the model. During the forthcoming quarter we will begin to develop a model of the magnetic field due to these currents that can be added to the polar current effects presently being analyzed.

During the next reporting period a paper entitled "A Technique for Modeling the Magnetic Perturbations produced by Field-Aligned Current Systems" by D. M. Klumpar and D. M. Greer will be presented at the Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy. The paper will present results of several trial runs of the modeling program and show how these compare with the typical high latitude perturbations observed at Magsat.

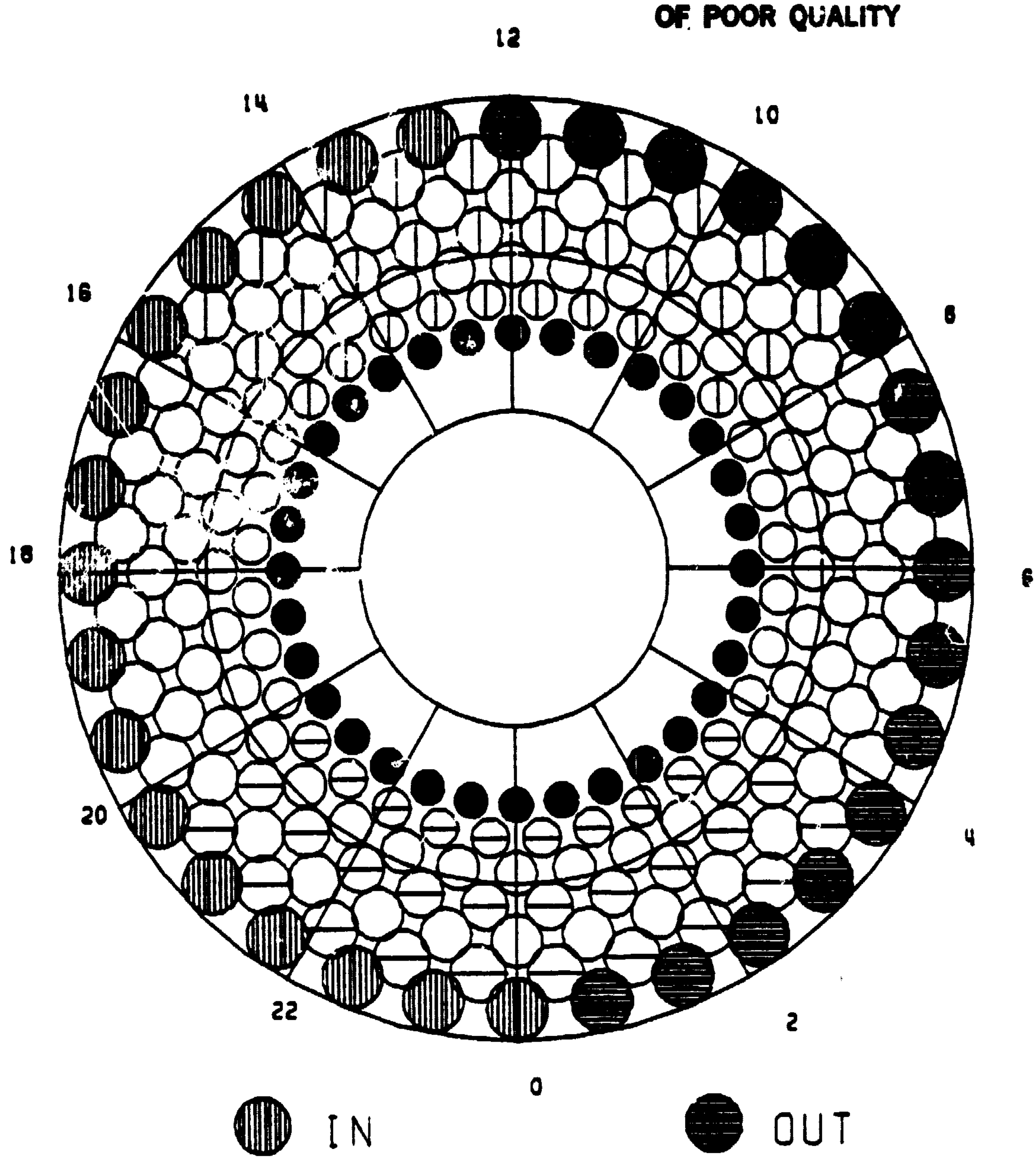

FIG. 1

DISTRIBUTION OF FIELD ALIGNED CURRENTS

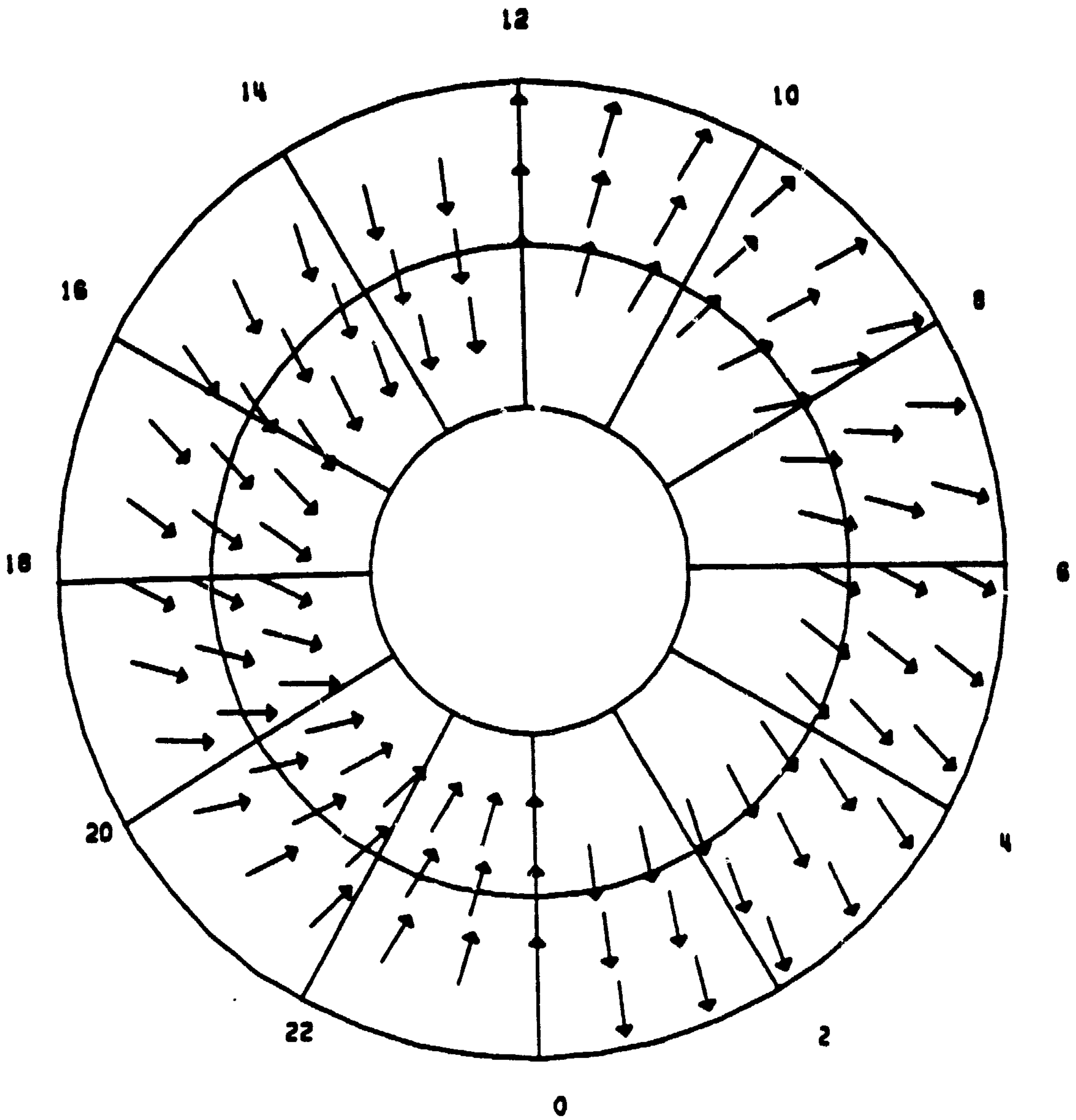

FIG. 2
DISTRIBUTION OF IONOSPHERIC CURRENTS

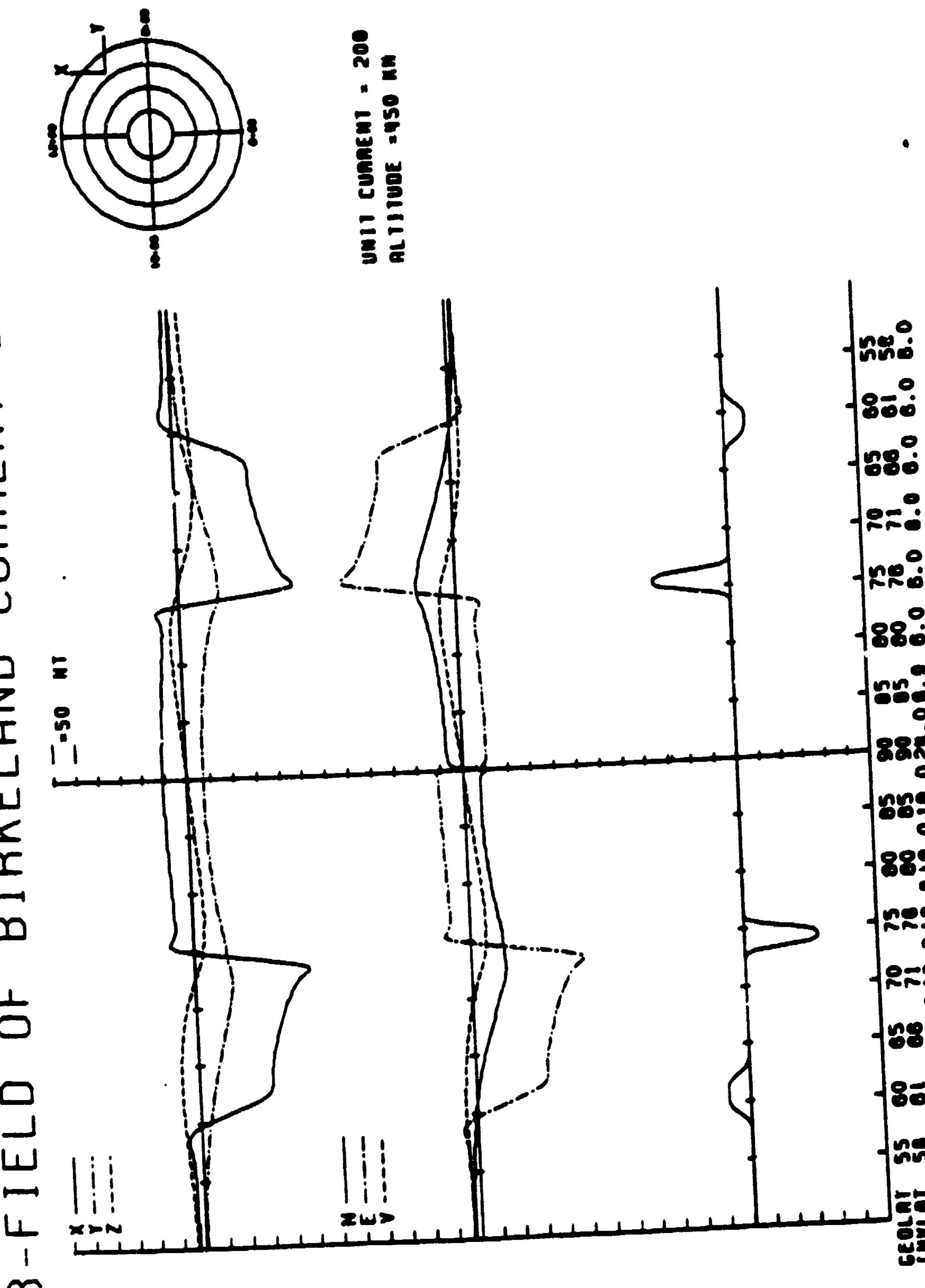
B-FIELD OF BIRKELAND CURRENT SYSTEM
UNIT CURRENT = 200
ALTITUDE =450 KM
=50 NT
X
Y
Z
N
E
V
GEOLAT
INVLAT
MLT

FIG. 3

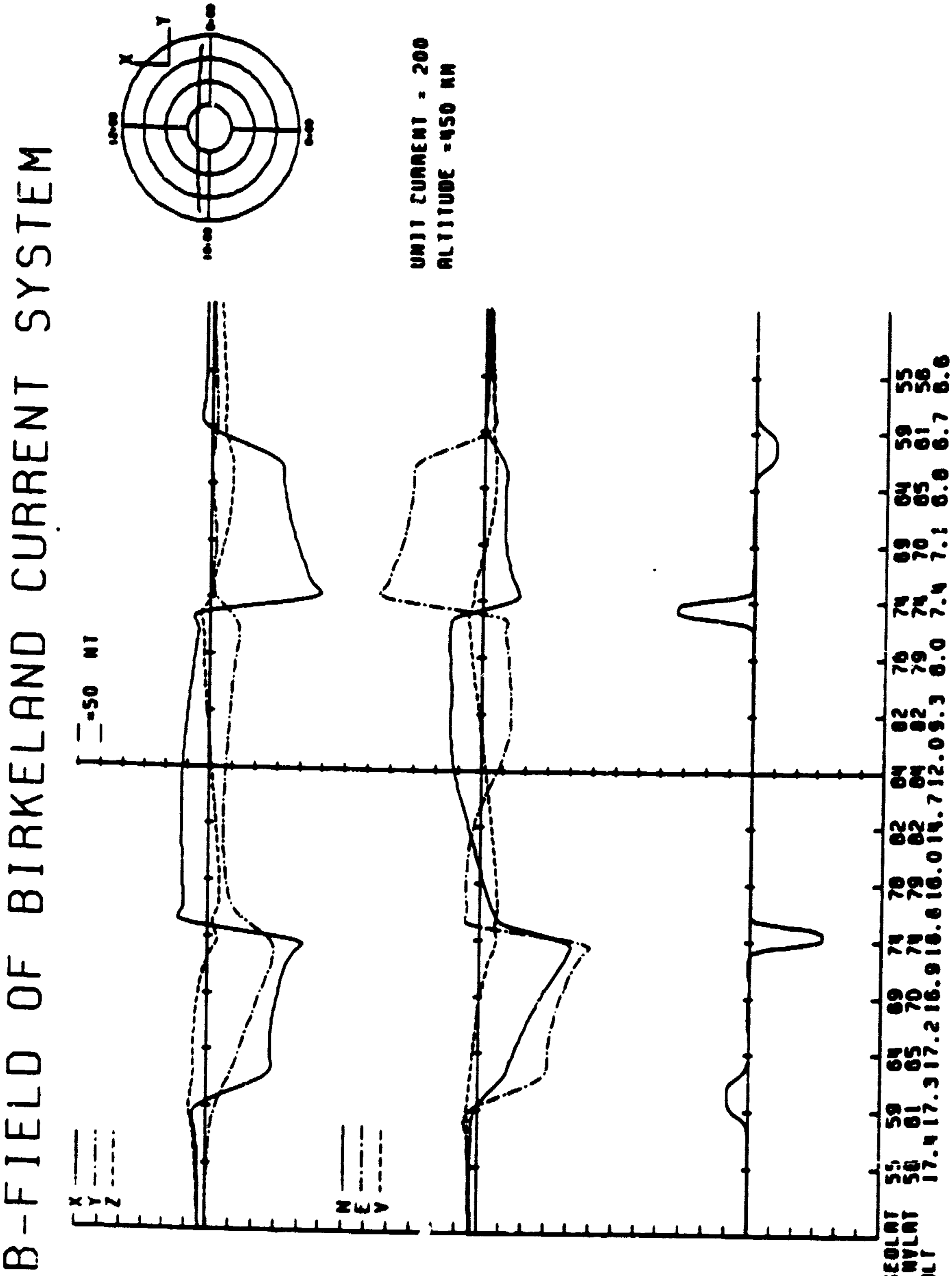
B-FIELD OF BIRKELAND CURRENT SYSTEM
UNIT CURRENT = 200
ALTITUDE =450 KM
=50 NT
X
Y
Z
N
E
V
GEOLAT
INVLAT
MLT

FIG. 4